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Physical Properties of Rocks

1510 Elasticity, structure, and flow of the Earth's crust: A review of the physical properties of rocks. The review covers the mechanical, electrical, and magnetic properties of rocks. The review is based on a survey of the literature published between 1970 and 1980. The review is organized into three main sections: (1) Elasticity, (2) Structure, and (3) Flow. The review is written by J. D. A. Foster and J. D. A. Foster.

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Planetology

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Selismology

1510 Seismology: A review of the physical properties of seismology. The review covers the mechanical, electrical, and magnetic properties of seismology. The review is based on a survey of the literature published between 1970 and 1980. The review is organized into three main sections: (1) Seismology, (2) Earthquake, and (3) Earthquake. The review is written by J. D. A. Foster and J. D. A. Foster.

Editorial

Education and Human Resources

The Committee on Education and Human Resources is charged with recommending to the AGU Council programs which will attract good students into geophysics, assist them in finding appropriate educational opportunities, and later help in identifying employment opportunities. This committee has the potential to be very important to the membership of AGU. We, the newly appointed members, have written this editorial to remind the AGU membership of this committee's existence and to solicit your ideas and advice so that we might achieve this potential.

One of the committee's recent projects has been the overseeing of a booklet entitled 'Careers in Geophysics,' aimed at the college undergraduate. The booklet tells what geophysicists do, what training they need, and where students can go for further information. Currently in press, 'Careers in Geophysics' will be available at no charge from AGU and should be a valuable recruiting tool. Another committee project included the determination of the value of classified advertising in *Eos*. By polling advertisers, this committee determined that the classified ads attract qualified candidates 80% of the time. The weekly nature and the short lead time for publication were emphasized as important. The study also showed that whereas advertising in journals such as *Eos* attracted 35% of successful appli-

cants, personal contacts ultimately led to the filling of 49% of positions. The committee is also supporting the creation of a Roster of Women in the Geoscience Professions by the American Geological Institute (AGI) Women Geoscientists Committee. This roster will include women from all sections of the AGU; such inclusion will be on a voluntary basis. Forms will be distributed via *Eos* in the spring.

There are two subcommittees, one on minority participation in geophysics and one on women in geophysics. Both are charged with recommending, developing, and assisting in the implementation of programs to encourage career opportunities that will lead to significantly greater participation of these groups in the geophysical sciences. The most visible responsibility of the minority subcommittee is representing the AGU in the AGI minority scholarship program. The most visible responsibility of the women's subcommittee is organizing the Women in Geophysics meeting at each AGU meeting.

What programs or policies do you feel our committee could implement to help you? We feel that one of our most pressing problems is how to attract good students into geophysics. One popular suggestion is to encourage the summer employment of undergraduates from disciplines other than geophysics. Do you have experience in this regard? What should the role of the AGU be in this process, informational only, or as a clearinghouse, matching students and employers? Have any other methods of attracting students worked for you? More generally, should AGU provide space for employers to interview potential employees at each AGU meeting? Would the provision of day care at AGU meetings allow you to attend a meeting that would be difficult for you to attend if it were not provided? Do you

Committee on Education and Human Resources
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Southern California Uplift— Is It or Isn't It?*

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Sandia National Laboratories
Albuquerque, NM

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The Southern California session of the fall 1980 John Muir Geophysical Society meeting was an attempt to answer the question of whether the Southern California Uplift was real tectonic deformation or merely an artifact of systematic survey errors. The three principal speakers were D. D. Jackson (UCLA), W. E. Strange (National Geodetic Survey), and R. Stein (Lamont-Doherty—formerly with the U.S. Geological

Survey). Jackson and Strange were arguing the negative side, i.e., that the uplift did not exist, while Stein argued that the uplift was real.

In leveling, observations are made so as to determine the height of permanent benchmarks, typically a kilometer or so apart relative to each other. Attempts are made to locate the marks on competent rock, although it is sometimes the case that marks are in fact placed in unconsolidated alluvium or in other soft ground, leading to unwanted instability. Additionally, real displacements are sometimes seen in alluvia that derive from non-tectonic causes, such as water withdrawal.

In connecting one benchmark to another, two 3.2-m rods and a transit level are used. Initially rod 'A' is placed upon the benchmark, while rod 'B' is erected on solid ground a few tens of meters away. The distance between rods is set by leveling standards and atmospheric and slope conditions. Prior to 1965, the interior distance could be more than 120 m, but since the mid-1960's, the distance is generally held to perhaps half the pre-1960 amount. The level is set roughly midway between the two rods, and several sightings are made on the graduated divisions scribed on each rod. Because both level and rods are erected as near vertical as possible, a calculation of the height difference between rods can easily be made. Rod 'A' is then leapfrogged up the slope several tens of meters beyond rod 'B,' and the measurement process is repeated. This continues until the required benchmark is reached.

As leveling progresses, many checks are made on the self-consistency of the measurements. For example, in double-rod leveling, a crew starts at benchmark 1, levels to benchmark 2, then levels back to benchmark 1. If the agreement is not satisfactory, the measurements are repeated. Another check is the closure of observed loops (cover). If leveling were carried out around the loop Sausalito-Lebec-Bakersfield-Mojave-Palmdale-Sausalito, for example, the net elevation change ought to be zero, unless tectonic or artificially induced motion has occurred during the survey. It is obvious, however, that if a systematic height-proportional error exists in the measurement process, neither of the above checks will suffice to detect it.

Jackson's thesis was that the uplift is a result of systematic errors. Misalignment of the level rods, amounting to several parts in 10⁴, can be documented, and resection errors are presumed to occur as well. Looking principally at the line segment Burbank-Sausalito-Palmdale over the years 1955-1965, Jackson pointed out that the elevation change is approximately 1 km and that much of the leveling route runs over alluvium, particularly in the Sausalito Valley, and may therefore be subject to some non-tectonic tilt. Additionally, if one of the rods is misaligned, the effect should show up in a scatter plot of apparent tilt between successive surveys against slope, the horizontal derivative of absolute elevation. In general, most of the points fall between two bounding lines with slopes of 10⁻⁵ and 10⁻⁴. Some of the scatter plots showed much better linear trends than others, and in some cases the slope of the regression line was determined by two or three outlying points.

The observed correlation between tilt and slope could be caused by true ground motion, or by systematic errors such as rod misalignment or refraction. Tectonic motion would not be expected to follow topography so closely, especially since topography is influenced largely by erosion, but local subsidence could produce tilts that are strongly correlated with slope. In at least two cases the correlation must be caused by rod misalignment because the alignment of the leveling route changed where rod changes were made. These changes took place at Sausalito in 1964 and near the present site of Pyramid Lake in 1966. One rod pair used in 1964 between

Sausalito and Pyramid Lake has been messed up other leveling as well and has even been recognized as faulty by the NGS. This rod was not involved in the change at Pyramid Lake, so that flagrant calibration errors (>10⁻⁴) exist in at least two rod pairs. The question that remained was whether other rods are seriously miscalibrated and whether true tectonic tilting remains after correcting for these errors. Jackson found that any residual tilts were not statistically significant, except in those cases where the tilt/slope ratio was determined by a few outliers.

Strange began his talk by asserting that rod error could not possibly be the cause of the uplift. Prior to 1916, wooden rods with inscribed brass strips were used, and calibration was the responsibility of the National Bureau of Standards. From 1916-1966, the United States Coast and Geodetic Survey maintained the rods. During 1916-1923, the USCGS calibrated the rods, but after 1923 responsibility returned to NBS. The rods in use from 1916-1929 were generally poorly scribed, but from 1929-1966 the rods were well scribed. Since 1968, rods have been obtained from the Kern Company and are calibrated by the NBS.

The standards of accuracy in use from 1923-1964 were that rods should be calibrated at 1-m intervals and should be correct to ± 100 ppm. From 1964 to the late seventies, calibrations were performed at 10-mm intervals and should have been correct to ± 30 ppm. Presently each division (10 mm) is calibrated to the ± 1 -ppm level. Calibration records of old rods showed that standards were met or exceeded. Rods made in 1931-1936 were found to be generally 40 ppm short, whereas rods from 1940-1950 were generally accurate to a few tens of ppm. Note that an error of 40 ppm corresponds to about 40 mm/km of elevation error. Note also that invar, which was originally chosen for its thermal stability, is dimensionally unstable at the level of a few tens of ppm, with a tendency to lengthen with time. Since the errors found in the old rods appear to be at or below specification in general, Strange concluded that systematic error caused by rod miscalibration could not be the cause of the uplift.

The error source that Strange favors as the probable cause is atmospheric refraction. Refraction occurs when the air near the ground becomes stratified because of temperature gradients, being hottest at ground level. The problem was studied in the '30s independently by Kukkamaki and Best. Both derived corrections for atmospheric refraction that depend linearly on the average temperature gradient between 0.5 and 2.5 m above ground level, linearly upon the measured height difference, and quadratically upon the sight length, the distance between transit level and rod. The principal uncertainty appears to be in the determination of the temperature gradient. Since nearly all of the leveling to date has not included temperature measurements, various schemes have been devised to estimate it, based on cloud cover, sun angle, time of day, and so on. The method selected by Strange was based mainly upon empirical considerations and was chosen partly to null elevation changes observed over the line California to Mojave from 1953-1973.

In order to validate the importance of atmospheric refraction, the NGS has recently carried out a series of tests at Galtherburg, Maryland, and Tucson, Arizona. At Galtherburg, 218 observations of a 2-m nominal elevation distance were carried out over sight lengths of 30 m, 45 m, and 80 m. Similarly, 238 observations were carried out at Tucson over the same sight lengths of the same elevation distance. At both sites, the observations were taken under a great variety of wind and atmospheric conditions. The observed elevations varied by as much as 65 mm from the nominal at Galtherburg and 150 mm from the nominal at Tucson for the 60-m sight length; Strange therefore concluded that refraction effects are and is probably a significant effect.

When refraction corrections were applied to the Southern California data set, most of the measured uplift went away. The only significant deformation remaining was localized near the San Andreas fault and in Cajon Pass. As a self-consistency check, corrected and uncorrected closures were computed. In all cases, the application of refraction corrections did not significantly degrade the closure errors, although many closures were not significantly improved either.

*A summary of the Southern California session of the John Muir Geophysical Society Meeting, October 6-8, 1980, Allamog, California.

EOS

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Cover: Cumulative uplift in southern California from 1959 through 1974. Elevation change contours taken from leveling data along lines shown, additional lines extending eastward and westward from the net shown, and the results from leveling commissioned especially to document the eastward extent of the bulge. (From United States Geological Survey Yearbook, p. 92, 1977).

Thus, corrected deformations are at least as plausible as uncorrected deformations, if closure error is the criterion. Stein contended that Jackson had grossly overestimated the impact of leveling rod error and argued that Strange's refraction correction has yet to be adequately tested. Stein showed that when tilt measured from resurvey was plotted as a function of topographic slope for 1100 km of routes that are too steep for significant refraction, the mean rod-related elevation-dependent error comes to $(0 \pm 5) \times 10^{-5}$ x the topographic height. In other words, the standard error for levels run over 1000-m topography is about 5 cm. The levels spanned the years 1953-1980; during this period the mean error was about constant. The error tends to cancel over several levels of a route or over more than about 80 km along one route. Since the error does not accumulate, it could not cause the 20-30-cm errors that would be required to interpret the uplift as a rod artifact.

Stein showed that when rod-related errors were removed from a sequence of levels across the uplift, 149 ± 17 mm of uplift results at Grapevine, north of the San Andreas fault at Tejon Pass, relative to Saugus, at the base of the San Gabriel Mountains, compared to 165 \pm 9 mm, using observed data. Strange applies less than 10 mm of refraction correction on those resurveys since the eight lengths were short and nearly the same for all levels, so this measure of uplift is independent of optical effects.

In his comments on Strange's presentation, Stein first pointed out that Strange's refraction-corrected uplift has approximately the same form as that of Castle, with half the observed amplitude; the difference is one of degree only. In fact the refraction correction of Strange usually amounts to less than 5 cm, and about one half of the Southern California routes do not change more than the random error. Stein showed that there are seven ways to get to Palmdale from Tidal B in San Pedro, and they all give very consistent results: no uplift between 1926 and the late 1950's, 20 cm by the only 60's, and an additional 15 cm by the early 70's. Since the routes traversed different terrain under different temperature and procedural conditions, Stein felt that this could not be coincidental.

Stein argued that the NGS refraction correction takes the assumed ambient temperature as a function of time of year and location to approximate what is presumed to be a stable nonlinear vortical temperature gradient. If the gradient is very unstable, or if it is stable but linear with height, no differential refraction would accumulate. A wind velocity gradient of only 3 m/s (its 4 m/s speed) would reduce the temperature gradient by 50% for Southern California conditions. Stein asserted that the behavior of refraction as a function of wind speed and ground thermal properties (e.g., frost, asphalt, railroad gravel) was unknown. Stein proposed that the USGS run a field experiment between Saugus and Palmdale this spring and solicited the help and expertise of the NGS for its operation. He also recommended that Strange test the NGS refraction correction on the 20 leveled circuits of the 1978 NGS Southern California Refueling Program to see if the correction significantly reduces the misclosures. Stein closed by showing a 50 km long San Gabriel Mountain leveling route that displays 13 cm of uplift during 1979-80. The same standards and procedures were used for both surveys. No more than 2 cm of this can be explained by rod or refraction corrections, which indicates that a mobile crust exists in Southern California and that this mobility is not confined to the 1980's.

During the discussion period which followed the presentation, it became apparent that all three had used much the same data but had come to markedly different conclusions. There was a question about whether movement of station Woody, in the Sierra Nevada, relative to Lebec, of some 209 mm was real and whether it represented movement at Lebec or at Woody. Another interesting point brought up by Jackson was that prior to 1964, the graduated marks on the rods were painted on after the calibration procedure was performed. Thus in these data there is some question about the validity of the calibration procedure. Stein pointed out, however, that even with this uncertainty, the various data from different lines are still relatively self-consistent.

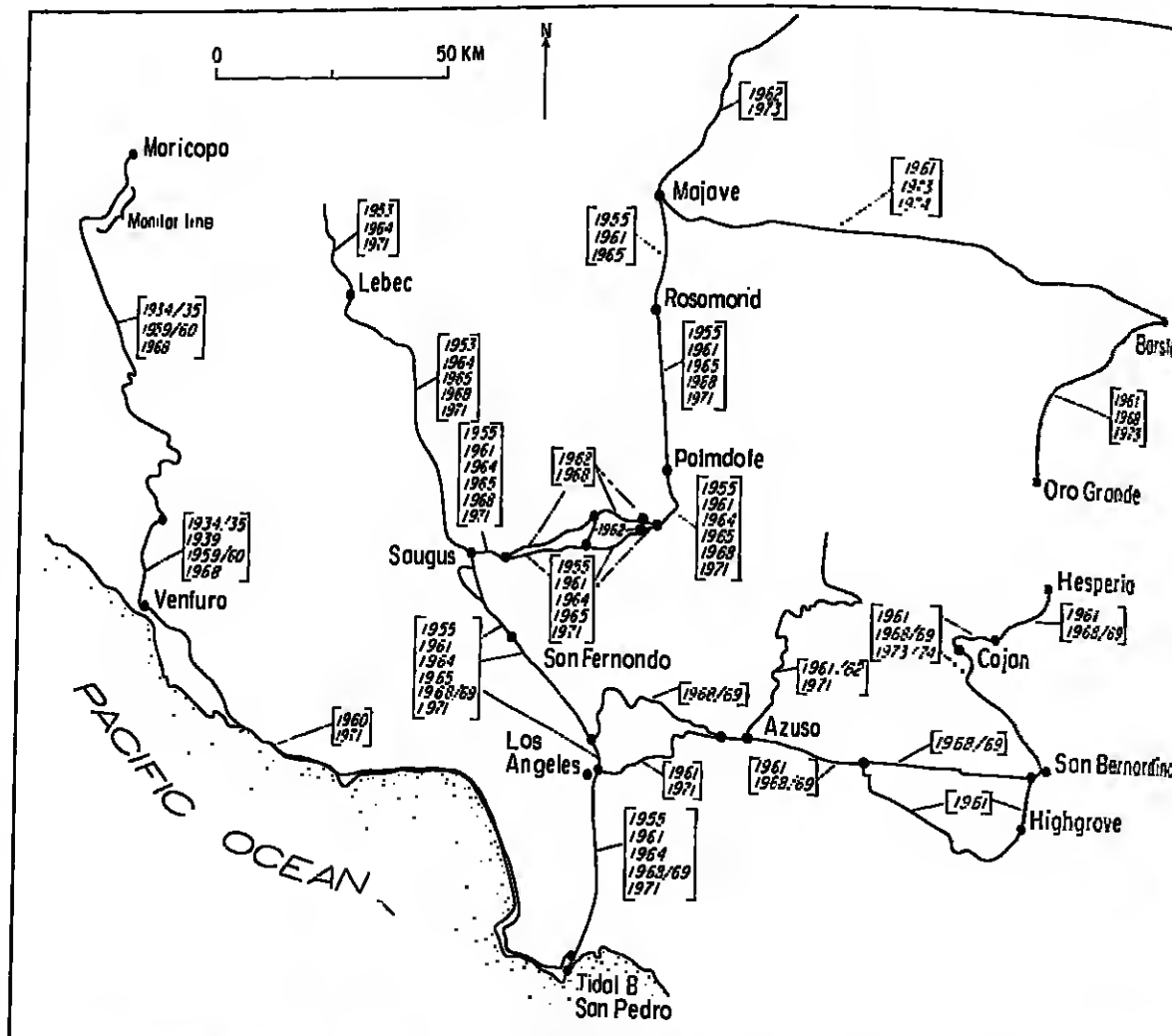
Jackson and Strange both commented that there was little redundancy in the earlier surveys (before the 1962 uplift). A further question concerned the likelihood that errors such as rod miscalibration and refraction would produce errors as consistent in space and time as the hypothetical bulge. Stein considered this unlikely. Strange suggested that the change in average sight length in the mid 60's could explain the temporal consistency. Jackson doubted the claimed temporal and spatial consistency of the uplift, but pointed out the change in calibration procedure in 1964, just in case.

A question from the floor concerned the reliability of leveling data on nearly level profiles. Stein and Strange suggested that they should be reliable. Jackson said that current models for refraction predicted negligible errors for slopes less than 1%, but that our understanding of refraction is not adequate to be sure of this. Rod miscalibration may be severe on mild slopes if successive readings repeatedly span a small kink in a rod.

Jackson also stated that when height-correlated errors exist over regions of uniform slope, the apparent tilt area also uniform and cannot be distinguished from uniform tectonic tilting. Thus variations in slope are required if systematic errors and tectonic tilting are to be distinguished. Unfortunately, many of the lines run along slopes, such as railroad track beds, that are nearly uniform for practical reasons.

The afternoon session began with a discussion by W. Thatcher (USGS) of a similar aseismic uplift on Izu peninsula in Japan from 1974-present. The uplift has a maximum amplitude of about 20 cm, is in an area noted for compressional tectonics, and is confirmed by gravity data whose maximum amplitude was $-40 \mu\text{Gal}$. Many of the lines which define the uplift run along the coast so height-correlated errors are not a problem. Additionally, the Japanese data had not been corrected for possible refraction effects.

R. Reilinger (Cornell) discussed some of the Southern California leveling data in greater detail. In particular he discussed data from the Saugus basin, an area of active groundwater withdrawal. The leveling data in this area show some apparent relative subsidence. Taken together with aquifer dimensions and properties, the possibility of near-surface subsidence is reasonable. Reilinger suggested that while some Southern California leveling measurements appear to reflect tectonic deformation, others are significantly affected by systematic errors and near-surface movements. He concluded that the configuration of the 'Palmdale Bulge' will, at the very least, require revision in light of improved understanding of those factors that can influence leveling observations. Although other leveling data in the U.S. is demonstrably contaminated by height-related errors, Reilinger concludes that the Saugus basin data show real deformation.



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Applications are due April 30, 1981. Inquiries, nominations, and applications should be sent to John W. Schuchman, Director, School of Geology and Geophysics, University of Oklahoma, Norman, OK 73019.

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Solid Planet Geophysicist/Texas A&M University. The Department of Geophysics at Texas A&M University is pleased to announce availability of a junior level, tenure track faculty position. The department emphasizes solid earth geophysics with concentrations in tectonophysics, geodynamics, and internal structure. We are seeking a talented and active researcher and teacher who will complement, strengthen, and broaden current areas of expertise. There are excellent opportunities for interaction and collaboration with members of our department as well as those in the departments of oceanography and geology and in the center for tectonophysics. Qualified candidates are requested to send resumes to: Travis L. Carter, Head, Department of Geophysics, Texas A&M University, College Station, TX 77843.

Texas A&M University is an equal opportunity employer.

The Hebrew University of Jerusalem. Structural Geologist/Geophysicist. Applications are invited for a tenure track position in structural geology and/or geophysics, to be filled at the senior lecturer or associate professor level, effective October 1981.

The appointee is expected to develop a strong research program and to offer courses in his own field of research and related subjects at graduate and undergraduate levels (including introductory and field courses) as well as to advise M.Sc. and Ph.D. students. The department carries out a vigorous research program and cooperation with other staff members is both possible and desirable.

Applicants should forward a curriculum vitae, list of publications and two letters of recommendation to the Chairman, Department of Geology, Institute of Earth Sciences, The Hebrew University of Jerusalem, Israel.

Assistant Professors in Atmospheric Science—Climate Dynamics. Qualifications: Ph.D. in atmospheric science or related field with strong background and evidence of experience in the theory, phenomenology, and numerical modeling of atmospheric motion systems and a demonstrated interest in the study of climate and its physical basis.

Teaching responsibilities include: numerical prediction course and sharing in teaching of one or two other undergraduate courses in basic and applied theory and phenomenology and one graduate level course.

Research focus is on climate, its emergence and dynamics. These studies would complement existing projects involving hydrologic cycles, regional evapotranspiration, trace gas transport and air pollution effects.

Applicants should submit resumes, transcripts, copies of publications, and the names and addresses of at least three references to: Dr. Bryan Webb, Search Committee, Department of Land, Air and Water Resources, University of California, Davis, CA 95616, by May 15, 1981.

The University of California is an equal opportunity/affirmative action employer and invites applications from all qualified individuals.

Research Fellow Aqueous Solution Geochemistry. The Australian National University invites applications for appointment to the position of research fellow—aqueous solution geochemistry, in the Research School of Earth Sciences from those holding a Ph.D. degree in a relevant field.

The Research School of Earth Sciences has recently established an interdisciplinary research group in environmental geochemistry. Current areas of research include application of stable isotope studies and radiochemistry, to the geochemical evolution of the Great Barrier Reef, the Gulf of Carpentaria and the geochemical record contained in the sediments of Australian inland lakes. Special attention is also being devoted to holocene paleoclimatology and the carbon cycle. This group wishes to appoint a research fellow specializing in aqueous solution geochemistry to work on a collaborative basis on research projects in the above areas.

In addition to participating in collaborative research programs, the appointee will have the opportunity of pursuing independent research in general areas of interest to the group. The geochemical environment of Australian inland lakes and groundwater is of particular interest and the appointee should be prepared to participate in a major research program aimed at understanding the role of transport and precipitation of chemical species in heterogeneous aqueous solutions and sediments. A wide range of evaporite minerals are known to occur in these basins at the present time.

Consequently, the research undertaken by the successful applicant may have implications not only to environmental geochemistry and paleoclimatology but also to economically significant topics such as the mobilization, fixation and migration of metals and other elements of economic significance.

Applicants should have broad interests in geochemistry, together with a strong background in theoretical solution geochemistry and relevant experimental techniques. In addition to describing their qualifications, applicants are invited to submit research proposals detailing the general research directions and specific projects in which they would wish to pursue. Further information concerning the position can be obtained directly from Dr. W. Compston.

Salary on appointment will be in accordance with qualifications and experience within the range: Research Fellow \$10,135–\$24,872 per annum. Appointment will be for 2 or 3 years in the first instance with the possibility of extension to five years. Superannuation, housing assistance, reasonable appointment costs.

The University reserves the right not to make an appointment or to make an appointment by invitation at any time. No fixed closing date is specified for the above position.

Interested candidates are requested to submit their applications to The Registrar, Australian National University, PO Box 4, Canberra, ACT 2600, Australia.

Assistant Professor: Hydrology/Water Resources. Tenure track appointment involving teaching and research in hydrology and water resources. Excellent opportunities for interdisciplinary collaboration with ecologists, meteorologists, geologists and hydrologists. Please call or send resume, transcripts, and names of three references to: George M. Hargreaves, Department of Environmental Sciences, Clark Hall, University of Virginia, Charlottesville, Virginia 22904.

Closing date for applications April 15, 1981.

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Geophysicist/Structural Geologist, Albion College. A tenure track position, commencing Fall 1981, is open at the assistant professor level at Albion College's Department of Geological Sciences. The position involves teaching undergraduate laboratory courses in structural geology and geophysics and introductory lab courses or non-lab courses in geology. The Department is developing a geophysics major and has some geophysical equipment. Candidates with a Ph.D. or who are about to acquire a Ph.D. are preferred.

Depending upon the applicant's background, the new staff member may have the opportunity to assist in teaching at Albion's geology field camp for additional remuneration. A 8-week summer field methods course is offered to students from many colleges and universities at the field camp located in the Front Range near Boulder, Colorado.

Albion College is a co-educational liberal arts college located in southern Michigan, an hour's drive from Michigan State University. The University of Michigan and Western Michigan University. The Department has four full-time members and 30 to 40 majors; it is a well-equipped department occupying a floor-and-a-half of a new science center.

Resumes, transcripts and three letters of reference should be submitted to: Prof. Lawrence D. Taylor, Department of Geological Sciences, Albion College, Albion, Michigan 49224.

Albion College is an equal opportunity employer.

Structural Geologist. The Department of Geosciences of Purdue University invites application for a tenure track faculty position in structural geology, starting in August 1981. Rank and salary will be commensurate with qualifications. A Ph.D. is required. The individual will be expected to teach undergraduate and graduate courses in structural geology and tectonics, participate in summer field courses, and pursue an active research program.

Preference will be given to a candidate with an applied field orientation and a strong background in the quantitative analysis of field data. The department has active programs in petrology, geophysics, and tectonophysics and has a close working relationship with the geological group in civil engineering and the Laboratory for Applications of Remote Sensing. Closing date for applications is April 1, 1981.

Applicants should send a resume, transcripts, and a list of references to: Dr. R. H. McCauley, Department of Geosciences, Purdue University, West Lafayette, IN 47907.

Purdue University is an equal opportunity/affirmative action employer.

Sedimentologist. The Department of Geology at the University of Illinois, Urbana-Champaign, has an opening for a tenure track position at the assistant professor level, beginning during the 1981–82 academic year. A Ph.D. is required. The applicant should have a strong background in geology, and post-graduate experience in sedimentology. Candidates with interests and experience in tectonic studies based on sedimentological observations will be given preference. The successful candidate is expected to develop an active research program to complement existing programs in geodynamics, solid earth geophysics, and rock physics. There is also opportunity for interaction with programs in the Department of Theoretical and Applied Mechanics and Civil Engineering, and the interdisciplinary Materials Research Laboratory. Send resume and names of three references to: Dr. John Hower, Head, Department of Geology, University of Illinois, 245 Natural History Bldg., 3301 W. Green St., Urbana, IL 61801 (Telephone: 217/333-3542). Applications should be received by April 15, 1981.

The University of Illinois is an affirmative action/equal opportunity employer.

Faculty Position University of Iowa. The Department of Physics and Astronomy anticipates one or two openings for tenure track faculty in August 1981. The successful candidates for which substantial resources are available are magnetospheric and solar physics and space and laboratory plasma physics, both theoretical and experimental. Other specialties of interest are astrophysics, elementary particle physics, atomic physics, condensed matter, and low energy nuclear physics. The positions involve undergraduate and graduate teaching, guidance of research students, and personal research. Interested persons should send a resume, a statement of research interests, and the names of three professional references to Search Committee, Department of Physics and Astronomy, University of Iowa, Iowa City, IA 52242.

The University of Iowa is an equal opportunity/affirmative action employer.

Geophysicist North Carolina State University—Raleigh. The Department of Marine, Earth and Atmospheric Sciences invites applications for a presently available tenure track position in geophysics. Rank and salary are open, depending on qualifications and experience. A Ph.D. is required. Applied or exploration geophysics orientation is preferable; however, other specializations in geophysics also will be considered. Primary responsibilities will include generating and conducting research programs as well as teaching graduate courses in geophysics. The department currently consists of 31 regular faculty members including 18 in the areas of geology and geophysics. Please send resume and names of three references to: Prof. L. J. Wronski, Search Committee Chairman, Department of Marine, Earth and Atmospheric Sciences, North Carolina State University, Raleigh, NC 27650, USA. We hope to make a final decision prior to May 31, 1981.

North Carolina State University is an equal opportunity/affirmative action employer.

Sedimentary Geologist/Micropaleontologist, Washington University. The Department of Earth and Planetary Sciences, Washington University, has available a tenure track, assistant professorship position, beginning in the 1981–82 academic year, for a geoscientist with research interests in diagenesis of sediments or in micropaleontology.

The successful candidate must have the following attributes: demonstrated creativity and promise of excellence in research and teaching; intent to develop a vigorous graduate research program; desire to teach courses in field of interest and related fields of geoscience at undergraduate and graduate levels.

Send resume, statement of future research interests, and names of at least three references, to: Larry Haskin, Chairman, Department of Earth & Planetary Sciences, Washington University, St. Louis, MO 63130. Applications received through April 15, 1981.

Washington University is an equal opportunity/affirmative action employer.

Vincent C. Kelley and Leon T. Silver Graduate Fellowships

THE UNIVERSITY OF NEW MEXICO

The Department of Geology of the University of New Mexico invites applications for the Vincent C. Kelley and Leon T. Silver Graduate Fellowships. The fellowships will be awarded on the basis of the academic record and academic promise of graduate applicants. Each fellowship will provide for a generous living stipend of \$1,000/month for 9 to 12 months, and up to \$2,000/year for travel and research expenses. The Caswell Silver Foundation will pay all tuition and university fees. The awards are made on an annual basis, but may be renewed for up to three years as long as the student maintains excellent academic standing and shows evidence of significant progress in research. Preference will be given to, but is not restricted to, applicants for the Ph.D. program.

An application for admission to the UNM Graduate Program, transcripts, Graduate Record Exam results (verbal, math & geology), three letters of reference and a brief statement of research goals are required for consideration for the fellowships. Application materials may be obtained from:

Rodney C. Ewing
Chairman
Department of Geology
University of New Mexico
Albuquerque, New Mexico 87131



The deadline for applications is April 1, 1981 for the Fall semester of 1981.

The Caswell Silver Distinguished Professorship in Geology

THE UNIVERSITY OF NEW MEXICO

The Department of Geology of the University of New Mexico is pleased to invite nominations or applications for the Caswell Silver Distinguished Professorship in Geology. This endowed professorship shall be awarded for periods of up to two years to earth scientists of distinguished accomplishment and international reputation. The professorship is the broadest honor and the major criterion for selection is that the recipient must carry out a vigorous research program while in residence at UNM. The recipient is expected to interact with the faculty and advanced topics of his/her choice, to provide one or more seminars, in-person and written, and to provide each academic year. The Foundation will provide unusually generous remuneration commensurate with the distinguished nature of the appointment. In addition, a travel support, analytical services in department laboratories, use of field vehicles, and preparation of manuscripts will be provided.

Applications or nominations should include a detailed resume and brief statement of major research accomplishments. Applications or nominations should be forwarded to:

Rodney C. Ewing, Chairman
Department of Geology
University of New Mexico
Albuquerque, New Mexico 87131



The Caswell Silver Foundation is an equal opportunity/affirmative action employer.

Economic Geologist. The Department of Geoscience at New Mexico Institute of Mining & Technology wishes to add staff members in the field of ore deposits and/or energy resources, petrology, structural geology and geomorphology to its existing staff. Applications with experience in any of these fields will be considered but preference will be given to those with proven capabilities in economic geology. If successful, candidates will be expected to develop an active research program in addition to participating in instruction. Rank open, send resume, transcripts, and names of three references to: Dr. A. J. Sudding, Chairman Search Committee, Geoscience Department, New Mexico Institute of Mining & Technology, Socorro, NM 87801. Closing date March 31, 1981.

AAEOE.

Sedimentologist. The Tennessee Earthquake Information Center (TEIC) is seeking applications for the position of sedimentologist beginning July 1981. The position will also be a joint tenure track appointment in the Department of Geology. Primary duties, however, are with TEIC; teaching will be on a semi-regular basis, not to exceed one course per semester.

The Ph.D. is required and experience with telemetry networks to highly desirable. The successful applicant will be expected to assume co-PI responsibilities on the Memphis and Southern Appalachian seismic networks, as well as actively pursue externally funded research projects digital data processing, seismic hazard assessment and public information for other aspects of the job.

The TEIC is a research organization of Memphis State University and the State of Tennessee, 12-month salary (\$25,000 and above) depends on background and experience. Position is 1/2 state supported, 1/2 (summer) from external sources.

Application deadline: 15 April 1981. Send resume, publications list, short statement of research interests, and names and addresses of four references to:

Arch Johnston, Director
Tennessee Earthquake Information Center
Memphis State University
Memphis, Tennessee 38152
Memphis State University is an equal opportunity/affirmative action employer.

Head/Earth Resources Branch, NASA/Dodder Space Flight Center. GS-1330-14/15: \$37,871-\$50,112 per annum, full-time permanent. The Earth Survey Applications Division, Applications Directorate, NASA/Dodder Space Flight Center invites applications for the open position of Head, Earth Resources Branch.

The incumbent of this position is responsible for planning, managing, and conducting broad programs in earth resources remote sensing basic and applied research and data analysis, emphasizing the development and demonstration of applications of remote sensing of earth resources from earth orbiting satellites. The primary areas of research in the Branch are land use management, vegetation science including agricultural/forestry/land and environmental monitoring utilizing remotely sensed data and advanced technologies. Also, significant effort is dedicated to sensor data evaluation in terms of applications and scientific utility, and to optimization of data acquisition and information extraction systems which best meet user scientific and resource management needs. An advanced degree in earth or physical sciences is required with education in the vegetation sciences, land use or environmental monitoring being specifically preferred. Candidates should also have several years of progressively more and more significant experience in the conduct, guidance and management of remote sensing research programs and clear evidence of a strong research background indicating senior research scientist status.

Resumes/SF 17's should be sent to: Dr. Robert D. Price, Assistant Chief
Earth Survey Applications Division
Code 920
Dodder Space Flight Center
Greenbelt, MD 20771
Deadline for applications is April 30, 1981.

Physicist Oceanographer. The Department of Marine Science and Engineering, North Carolina State University, has an immediate opening for a postdoctoral research associate. Research will be directed toward equatorial circulation dynamics, including seasonal and higher-frequency variability. Participation in fieldwork will be required. Qualifications include a Ph.D. or equivalent in physical oceanography or geophysical fluid dynamics and experience in the analysis of oceanographic time series. The initial appointment will be for 2 years, with a possible continuation subject to availability of funds. Salary is competitive and negotiable, based upon qualifications. Applicants should send the names of three references, a resume, and publication list to Robert H. Weisberg, Department of Marine Science and Engineering, P.O. Box 8620, NC State University, Raleigh, NC 27650.

Physicist Oceanographer. A grant-supported, postdoctoral or research associate position is available for theoretical and/or experimental work on bottom boundary layer and turbulence on the shelf, or on nearshore processes. A Ph.D. is required. Submit applications, with names of three references, before May 1, 1981 to Dr. David Huntley, Department of Oceanography, Dalhousie University, Halifax, Nova Scotia, Canada, B3H 4J1.

Geophysicist. The Geology Department at the University of Southwestern Louisiana in Lafayette, Louisiana, invites applications for an anticipated research position in geophysics. Responsibilities will include one-half time in seismic investigation of geosynclinal basins and one-half time in supervising and supervising graduate students. The successful candidate will be familiar with exploration seismic data acquisition, processing, and interpretation. The Ph.D. is required with experience, is required. Salary range \$23,000 to \$35,000 per 12 month.

The position is expected to be filled in the Spring of 1981 or as soon as possible thereafter.

To apply please direct a resume, three letters of recommendation, and any other pertinent materials to: Dr. Gary L. Kinsland, Geology Department, University of Southwestern Louisiana, Lafayette, LA 70504.

Geochronology/Brittle Deformation, University of New Brunswick. The Department of Geology has a tenure track position available from July 1, 1981 at assistant professor or higher level. The successful applicant will be expected to teach both undergraduate and graduate as well as carrying out research and supervising graduate students.

Applications will be accepted in the following fields: geochronology of ore bodies, exploration, environmental or soil geochronology, brittle deformation, rock mechanics or soil engineering. Applicants should have a Ph.D. and preferably post-graduate experience. Applications including curriculum vitae and names of three references should be sent to P. F. Williams, Chairman, Department of Geology, University of New Brunswick, Fredericton, N.B. E3B 5A3.

Battelle, Pacific Northwest Laboratories. Applications are invited for a postdoctoral position in geophysics with emphasis on middle or upper atmospheric research at the Battelle Observatory in Richland, Washington. Depend will be \$18,000 initially. The position offers the possibility of a permanent research position at a later date. A postdoctoral appointment. Address inquiries to: R. A. Blakes, Battelle Observatory, Settle, Pacific Northwest Laboratories, P.O. Box 998, Richland, WA 99352.

Northern Arizona University. Tenure track position in the department of physics. Presently planning early implementation of a masters degree program in atmospheric science. Candidate expected to contribute to research program. Teaching may be in undergraduate physics program as well as atmospheric science. Assistant or associate professor level. W. R. Willis, Box 2010, Northern Arizona University, Flagstaff, AZ 86011.

Faculty Position in Physical Oceanography. The Department of Marine, Earth and Atmospheric Sciences at North Carolina State University invites applications for a tenure track position at the assistant or associate professor level for a physical oceanographer, specializing in the numerical modeling of oceanic flows.

Applicants should have a strong background in geophysical fluid mechanics and the abilities to develop a funded research program and graduate level courses. Presently funded areas at NCOS include sedimentary, coastal and deep-water oceanography.

Send curriculum vitae and the names of three references by March 31, 1981 to Professor G. S. Jenzowicz, Chairman, Search Committee in Physical Oceanography, Department of Marine, Earth and Atmospheric Sciences, North Carolina State University, P.O. Box 2608, Raleigh, NC 27650.

North Carolina State University is an equal opportunity/affirmative action employer.

Sediment Transport/Geological Oceanography, North Carolina State University. A tenure track position is available in the Department of Marine, Earth and Atmospheric Sciences at the level of assistant or associate professor. Applicants should have a thorough understanding of sediment transport, and a general background in geological oceanography. A Ph.D. is required. The candidate will be expected to strengthen the graduate teaching and research programs. The applicant's research interests can be theoretical, experimental, or observational, but must involve quantitative examination of marine sediment transport. Applicants should forward a resume, including a list of courses taught, and the names of at least three references to: Dr. Charles A. Nittrouer, Chairman, Search Committee, P.O. Box 2608, NC State University, Raleigh, NC 27650. Application materials should be sent by March 31, 1981.

North Carolina State University is an equal opportunity/affirmative action employer.

Faculty Appointment/Colorado State University. The Department of Earth Resources, Colorado State University invites applications for a tenure track appointment with emphasis on active research experience in remote sensing, and an interest in teaching graduate and undergraduate students beginning September 1981. The candidate is expected to have a Ph.D. degree in geology, watershed sciences or in a related field and is expected to develop and maintain a vigorous research program with special emphasis on the application of state-of-the-art remote sensing techniques to the investigation of natural resource phenomena. The candidate is expected to teach undergraduate and graduate courses in the application of remote sensing to natural resources.

Rank and salary are open and dependent on experience and qualifications of the applicant.

Applicants are invited to submit curriculum vitae, three letters of reference and a letter describing research and teaching interests to: Dr. H. B. Boyne, Department of Earth Resources, Colorado State University, Fort Collins, Colorado 80523(303) 491-5229.

Deadline for receipt of applications is April 15, 1981.

CSU is an EOE/AA, E.O. Office: 314 Student Serv. Bldg.

Faculty Position/Synoptic Meteorology. The University of Maryland invites applications from qualified scientists for a tenure track faculty position at the assistant or associate professor level, commencing Fall 1981. Candidates must have a Ph.D. in meteorology or related area and have an area of specialization in synoptic and dynamic meteorology. Teaching and research experience is desirable. The successful candidate will be expected to teach primary graduate level courses in synoptic meteorology and carry on an active research program. Salary will be commensurate with qualifications and experience.

All applicants should send curriculum vitae, a brief statement of research interests and names, addresses and telephone numbers of three professional references to: Professor Ferdinand Beer, Chairman, Department of Meteorology, University of Maryland, College Park, Maryland 20742. Closing date for applications is April 15, 1981.

The University of Maryland is an equal opportunity/affirmative action employer.

Director Meteorology Division, Air Force Geophysics Laboratory. Air Force Geophysics Laboratory invites applications for the position of Director of the Meteorology Division located at Hanscom Air Force Base, Massachusetts. The Division is responsible for Air Force research and development in meteorology, atmospheric physics, remote and direct sensing technology, climatology, and relative technologies. The division director provides overall direction to an R&D program which employs over 30 people and covers a broad range of in-house and contractual scientific investigation. A candidate should have a record of distinguished achievement in meteorology/atmospheric physics as a research scientist and manager of a substantial R&D unit. This position is Air Force Senior Executive Service with a salary range of \$52,247 to \$57,673, subject to current 501.12 ceiling. For an application package, call collect: Robert Ellerin, (617) 881-2698. To be considered, applications must be returned by 30 April 1981.

Equal employment opportunity employer.

Senior Hydrogeologist. Fred C. Hart Associates, an environmental consulting firm, is providing technical assistance to the U.S. Environmental Protection Agency in its efforts to discover and identify hazardous waste sites, evaluate their impacts and design site clean-up measures.

An opening exists for the position of senior hydrogeologist in our Newark, N.J., office. The successful candidate will have field and management experience in groundwater contamination and will be responsible for developing monitoring programs and alternative solutions to contamination problems.

Candidates should possess an M.S. degree with five years field experience in hydrogeology, or B.S. degree and seven years field experience in groundwater contamination studies. Please forward resume to: Fred C. Hart Associates, Inc. 155 Washington Street, Newark, N.J. 07102, Attn: Amelia J. Janisz.

Chemical Oceanographer. Research associate, M.S., marine organic geochemistry and the relation to ocean productivity. Cooperative Institute of Marine and Atmospheric Sciences, University of Miami and National Oceanic and Atmospheric Administration, contact Chairman Search Committee, D. K. Atwood, NOAA/NOAA, 15 Rickenbacker Causeway, Miami, FL 33149.

Van Braun Post-Doctoral Fellowship in Space Physics/University of Alabama in Huntsville. Appointment effective September 1981 in a tenure track assistant professorship with reduced teaching load during the first two years. Research specialty in astrophysics, planetary science or solar terrestrial physics. Research support available from NASA, NASA and Radiation Aeronautics. Recent Ph.D.s are invited to send research proposals and names of four references. Apply to: Van Braun Fellowship Committee, Office of Academic Affairs, University of Alabama in Huntsville, AL 35899.

Equal opportunity in education and employment.

Research Associate. Position available July 1 for new Ph.D. scientist in climatology-geology. Work involves research in ice-climate synoptic interactions based on analysis of satellite imagery and ground-based data (Nimbus and DMSP systems) of meteorological and cryospheric parameters using multivariate statistical techniques. Research is performed in a cooperative university/government laboratory employing scientists engaged in interdisciplinary work related to the environment.

Position requires experience in analysis and display of remote sensing data and in data processing; demonstrated ability to write scientific reports; background in geoclimatology-meteorological field research in polar areas; experience in interpretation of snow cover, sea ice, and cloud conditions from visible, IR, and ESMR microwave imagery and digital data; experience with multivariate statistical analysis techniques, especially as applied to meteorological or related data; experience in FORTRAN programming in a CDC/Kronos or NCS operating environment; and research experience in synoptic climatology and ice-climate interactions.

Salary approximately \$17,000/year. Applications including vitae and three references should be addressed to Dr. R. G. Berry, CIREB, Campus Box 449, University of Colorado, Boulder, CO 80309. The University of Colorado is an equal opportunity/affirmative action employer.

Lunar Curatorial Laboratory: Manager.

Northrop Service, Inc. has operated and maintained the NASA Lunar Curatorial Laboratory at the Johnson Space Center, Houston, Texas since its inception. We are now searching for a manager candidate with a Ph.D. in geology or geochemistry, evidence of administrative skills and a record of publication in the study of lunar complex and/or meteorite investigations. Position involves the supervision of 36 technical, scientific and clerical employees. Interested persons should send resume, including publications and references to: W. B. Kurz, Manager of Personnel Services, Northrop Service, Inc., P.O. Box 3441B, Houston, TX 77034.

NSI is an equal opportunity/affirmative action employer.

COURSES

Flood, Predictions, and Forecasting. June 28 to July 3, 1981. The objective is to present various methods for floods by well known lecturers. Physical understanding will be emphasized. Lecture notes are specifically written for this course. Contact: H. W. Shen, Course Director, ERC, Colorado State University, Fort Collins, CO 80523. USA. Telephone (303) 491-8552. TWX 910-930-9000 ENGR CSU FTN.

SERVICES

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RESEARCH POSITION

THE INSTITUTE OF GEOPHYSICS AND PLANETARY PHYSICS and THE SCRIPPS INSTITUTION OF OCEANOGRAPHY UNIVERSITY OF CALIFORNIA

The Institute of Geophysics and Planetary Physics and the Ocean Research Division of Scripps Institution of Oceanography are considering an appointment in the research series to join in research on electrical conductivity of the ocean floor with special emphasis on active source methods.

The successful applicant (Ph.D. or equivalent) will design and implement experiments at sea, carry out theoretical analyses of electromagnetic propagation and interpretation of observations. Qualified candidates should have experience in related theoretical and experimental work. Seagoing experience and broad familiarity with geophysics are desirable.

Salary will be in the range of \$21,600–\$44,000, depending on experience.

Applications with supporting data and references should be sent by June 1, 1981 to

R. E. Davis
Chairman
Ocean Research Division (E) A-020
Scripps Institution of Oceanography
La Jolla, CA 92093

The University of California, San Diego, is an equal opportunity/affirmative action employer.

